Storage and Retrieval of Ground-Water Data at the U.S. Geological Survey
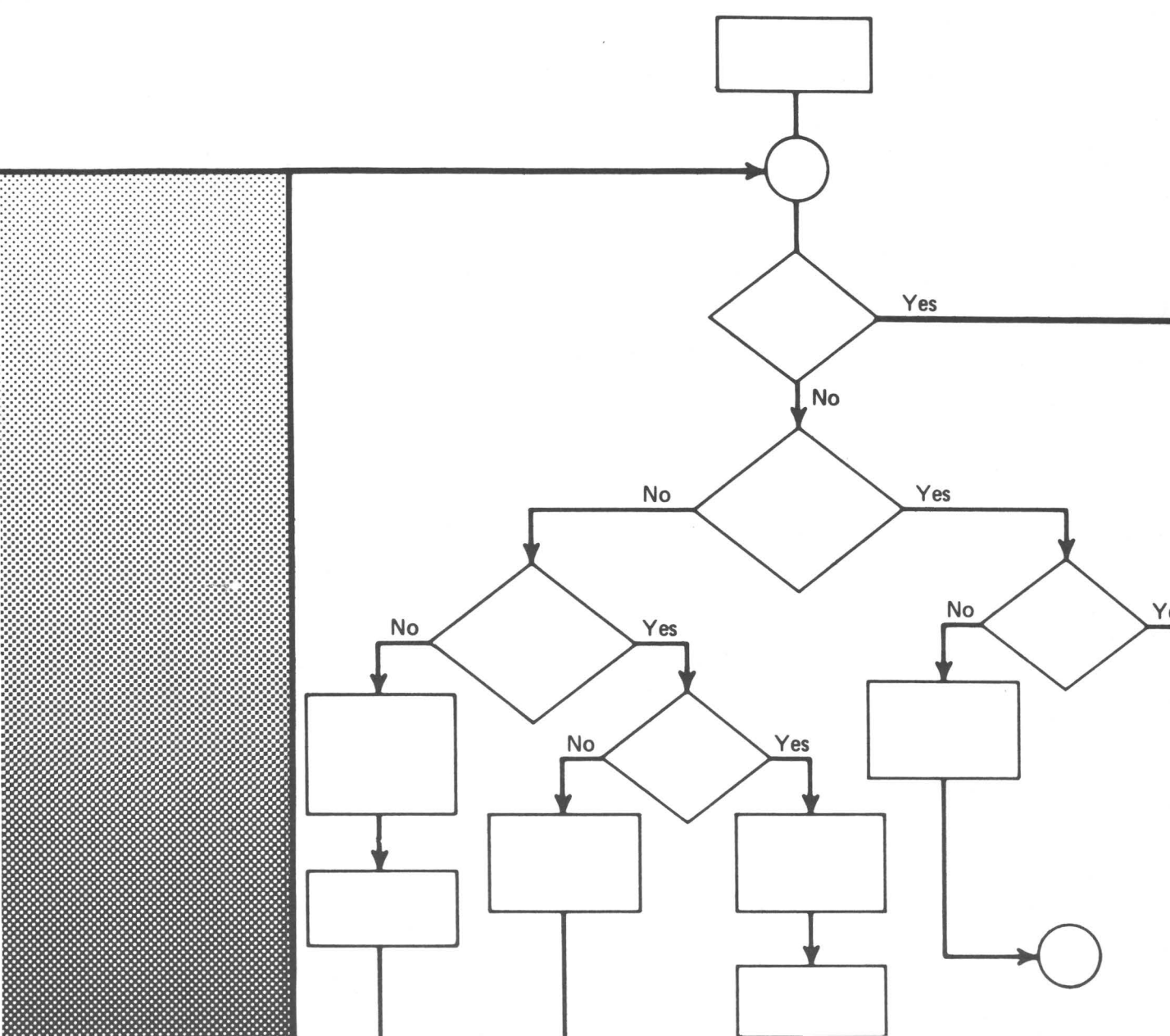
Yes

No

No

Yes

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Yes

No

Yes

No

Yes

Storage and Retrieval of Ground-Water Data at the U.S. Geological Survey

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ABSTRACT

The U.S. Geological Survey maintains a computerized Ground-Water Site-Inventory (GWSI) file that contains information about wells and springs at sites from all States of the United States. This file contains data collected by U.S. Geological Survey personnel and personnel of cooperating State, local, and Federal agencies. The file is easily accessible to members or users of the National Water Data Exchange (NAWDEX). Since the establishment of the GWSI file in 1974, the data base has grown 19 percent per year and contains information on about 770,000 sites as of February 1981.

INTRODUCTION

In the mid-1960's, ever-increasing amounts of data and a need for timely access to these data necessitated computerized data banks for the storage of information such as personnel records, daily business and financial records, and, in the case of the U.S. Geological Survey, hydrologic records. In keeping with one of the Survey's missions, that of collecting and publishing information about the Nation's natural resources (U.S. Geological Survey, 1981), the Survey created and maintains a central storage facility for water resources data known as the National Water Data Storage and Retrieval System (WATSTORE), at its National Headquarters in Reston, Va. Included in this computerized storage facility are representative ground-water data collected throughout the United States. This ground-water information resides in an online computer data file, which is maintained by a Data Base Management System (DBMS) called SYSTEM 2000[1] (MRI Systems Corp., 1974a). The name and acronym given this data base is the Ground-Water Site-Inventory (GWSI) file.

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[1]The use of brand or company names in this report is for identification purposes and does not constitute endorsement by the U.S. Geological Survey.

PURPOSE

As demand for ground water increases, the availability of site-specific ground-water data becomes very important in solving such problems as those involving water-supply and waste-disposal operations. To make competent management decisions concerning these problems, all available ground-water data in the vicinity of a site should be scrutinized as part of the evaluation process. This paper describes the various ground-water data elements that reside in the GWSI and explains how these data are entered and retrieved.

HISTORY OF THE GWSI

Twenty years ago, ground-water data collected in field offices by Survey hydrologists were stored in filing cabinets, many times on locally devised nonstandard inventory forms. During the 1960's, an attempt was made within the Survey to establish a standard approach to the storage of ground-water data in a national computer file (Lang and Leonard, 1967). Because of the specialized needs of hydrologists in diverse climatic and geologic areas of the country and the limitations of the data system, the national computer file was not used widely.

Because of the increasing demand for timely ground-water data, a need arose to redesign the structure of the data system to satisfy more fully the requirements of hydrologists and to establish a centrally controlled computer file that could be easily accessed by all users. A decision was reached in the early 1970's to obtain a commercially developed computerized DBMS to organize and maintain this file of raw ground-water data. The GWSI was designed and implemented in 1974, as documented in the "WATSTORE User's Guide, Volume 2" (U.S. Geological Survey, 1975), using the newly acquired

DBMS, SYSTEM 2000. The chief purposes of the GWSI are (1) to meet the need for storage of nationally standardized ground-water data and (2) to provide nationwide computer access to these data.

Because nationwide ground-water data are stored in one easily accessible computer file, the GWSI is a very useful tool for interpreting the hydrogeology of an area. An organization using the GWSI to work on projects throughout the Nation needs to learn only one retrieval technique to obtain the output in a standard format; this allows more time for the analysis of the findings. The tedious computer programing required for adjusting to different data sources is eliminated by using the standardized GWSI data base.

STRUCTURE OF GWSI

The structure of a SYSTEM 2000 data base is hierarchical, sometimes called a tree structure (see fig. 1). The top node (box) of this treelike structure is, in fact, the root, and, if turned upside down, the structure resembles a tree with its limbs branching upward. The top node, called ENTRY, which contains a unique identification number and location information for a ground-water site, can have many descendants (branches downward). However, no descendants may have more than one parent (branches upward). Figure 1 illustrates these relations. EN-TRY, the top node, has descendants, including LIFT, CONSTRUCTION, and GEOLOGY data. However, LIFT has only one parent, ENTRY. Each of these nodes, called schema records, contains up to 46 components of site information leading to 270 possible data items per site. Not all 270 possible data items are coded for any one site. Some items are unique to specific site types; for example, springs. If a ground-water site contains only the data listed in the top node (ENTRY (location data)) then only these data are in the file. The other schema records are not established until pertinent data are entered into the GWSI and, thus, do not occupy valuable computer disk file space. The SYSTEM 2000 DBMS uses indexing techniques to keep track of the locations of data items that are stored randomly in an online computer disk file. This indexing feature simplifies the addition of data to the GWSI file and makes retrievals more efficient.

COLLECTION OF DATA FOR GWSI

The bulk of the data in the GWSI file is collected by Survey personnel as part of water-resources investigations and water-level monitoring programs, in cooperation with State and local governments and other Federal agencies. Typically, data are collected by a hydrologist who inventories wells or springs by
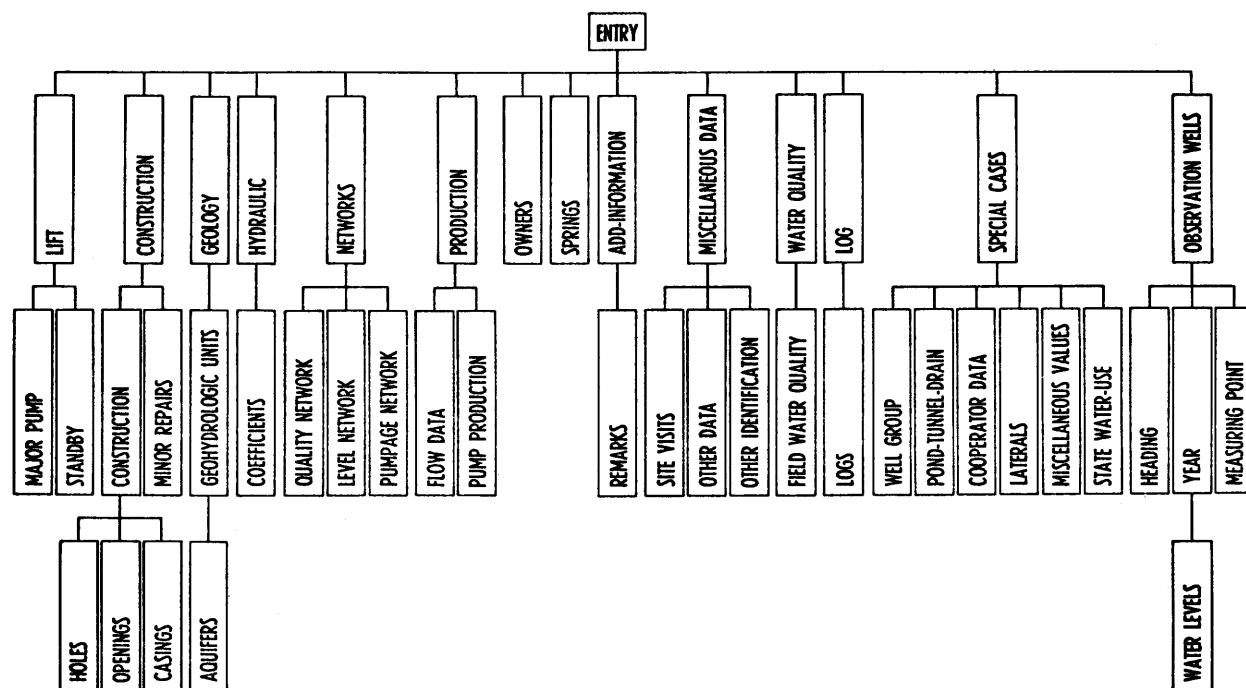

FIGURE 1.—Hierarchical structure of GWSI data base.

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examining them in the field. The information obtained is transcribed onto standard forms designed for the recording of data for input to the computer file.

Most data in the GWSI file are raw ground-water data entered by the inputting agency. Few statistical items are stored because these values can be readily calculated from raw data residing in the data base. Some of the categories of data that can be stored in schema records for each site in the GWSI are listed in table 1. Table 1 describes the schema records in figure 1 starting with the top node ENTRY, proceeding down each branch, then left to right.

TABLE 1.—*Description of GWSI schema records*
[For a detailed explanation of all components within each schema record available in the GWSI see "WATSTORE User's Guide, Volume 2," Chapter II, Section B]

Schema record	Description of information
ENTRY	Site identifiers such as latitude and longitude, altitude, State, county, and so forth.
LIFT	Type, such as pump or bucket; includes horsepower, intake setting, and so forth.
MAJOR PUMP	Manufacturer, serial number, energy consumption, capacity, and so forth.
STANDBY	Alternative power types.
CONSTRUCTION	
CONSTRUCTION	Date of completion, contractor, seal type, finish, and seal bottom.
HOLES	Type of well and dimensions, including diameter of top and bottom of hole.
OPENINGS	Depth intervals of perforated zones, size and shape, and screen material.
CASINGS	Type and material, top in reference to land surface, depth to bottom, and diameter of each string.
MINOR REPAIRS	Repair information.
GEOLOGY	
GEOHYDROLOGIC UNITS	Name of formation, including unit identifier and its depth.
AQUIFERS	Includes static water level in aquifer.
HYDRAULIC	Includes the unit identifier.
COEFFICIENTS	Includes conductivity, diffusivity, and leakance.
NETWORKS	
QUALITY NETWORK	Water-quality network, including name of agency that gathers samples at site.
LEVEL NETWORK	Water-level network, including name of agency that collects water-level measurements at site.
PUMPAGE NETWORK	Pumpage network, including name of agency that monitors water withdrawal at site.
PRODUCTION	
FLOW DATA	Information about springs, including flow period and discharge.
PUMP PRODUCTION	Production of the well, including production date and method.
OWNERS	The site's owner, name, and ownership date.
SPRINGS	Spring data; for example, name and number of openings.
ADDITIONAL INFORMATION	
REMARKS	Additional remarks about the site.
MISCELLANEOUS DATA	Other references and sources of data.
SITE VISITS	Visits to the site, such as the inventory person and date of visit.
OTHER DATA	Location and formats of other data available about the site.
OTHER IDENTIFICATION	Other site identifiers.

TABLE 1.—*Description of GWSI schema records*—Continued

Schema record	Description of information
ENTRY—Continued	
WATER QUALITY	
FIELD WATER QUALITY[1]-------------	Field water-quality data, such as the sample date, the constituent, its measurement, and source (aquifer name).
LOG	
LOGS ----------------------------	Type of geophysical or other logs available for the well, including type and source.
SPECIAL CASES	
WELL GROUP-----------------------	Multiple wells that are manifolded to a single discharge pipe, including the number of wells and the deepest and shallowest wells in the group.
POND, TUNNEL, DRAIN--------------	The length, width, and depth of a pond, tunnel, or drain.
COOPERATOR DATA-----------------	Data that cooperating local agencies need, such as cooperator's site identifier, registration number, and so forth.
LATERALS-------------------------	Information about Ranney wells, including the depth, length, and diameter of the laterals that drain to the central well.
MISCELLANEOUS VALUES-----------	Data for which no other schema record has been established.
STATE WATER USE -----------------	The State's use of water, including water type and the amount of water.
OBSERVATION WELLS	
HEADING--------------------------	Textual information about the site.
YEAR-----------------------------	Specific year for data in the lower level schema record(s).
WATER LEVELS-------------------	Includes water-level measurements and respective dates.
MEASURING POINT----------------	Includes the measuring point height and the date when the measurement was made.

[1]Although several field collected parameters of water-quality data (including temperature, conductance, and pH) are stored in the GWSI, the bulk of water-quality data reside in a nationwide file called *Sto*rage and *Ret*rieval (STORET), a file maintained by the U.S. Environmental Protection Agency (1973). The *Na*tional *Wa*ter *D*ata *Ex*change (NAWDEX) Local Assistance Centers provided in table 2 are authorized users of the STORET file and may retrieve ground-water-quality data for its subscribers.

QUALITY CONTROL AND ENTRY OF GWSI DATA

All ground-water data input to the GWSI data base should be reviewed for accuracy. The primary quality control measures are the responsibility of the inputting office. Once that office is satisfied that the data on field forms are correct, these data are transcribed to the format required for entry into the computer; for example, punched cards. Before entry into the GWSI file, the data are checked for logic and syntax errors by the inputting office by using a computerized verification system. This series of computer programs provides several types of error checks, such as (1) *syntax check,* which ensures valid input data (for example, correct codes are used and alphabetic characters are not entered where numeric data belong); (2) *compatibility check,* which ensures compatibility between data elements that are being entered or between input values and those that already reside in the data base (the depth to water, for example, cannot exceed the depth of the well); and (3) *out-of-range check,* which indicates whether input data fall within the bounds of certain parameters provided in tables in the computer programs

(for example, maximum and minimum values of latitude, longitude, and altitude reside in the tables for each State).

Input data will be entered into the GWSI file by the GWSI Data Base Manager (DBM) at the Survey's National Headquarters when all data have passed the error checks. All reports concerning final verification of the update process to the GWSI are sent to the originating office.

The inputting office may not directly update the GWSI data base. Only the DBM may update. Once the data are in the GWSI file, the inputting office must verify these data and correct any errors, such as transposition of numbers or misspelling of names that were not detected earlier in the proofing process. Erroneous data can be modified easily by the inputting office.

Non-Survey organizations that wish to enter data into GWSI must establish access to the data base by registering with the NAWDEX Program Manager. Detailed information about accessing the GWSI is discussed in a subsequent section entitled "Users and Use of the GWSI." Non-Survey organizations may obtain standard forms for encoding input informa-

tion in the GWSI format by contacting GWSI personnel of the Survey at the National Headquarters.

Since the inception of the GWSI file, the data base has grown at an average of 19 percent per year and contains information related to about 770,000 sites, as of February 1981. Figure 2 indicates the growth pattern for the past 3 years. The number of groundwater sites for which data have been entered into the GWSI file for each State, including Puerto Rico, is shown in figure 3.
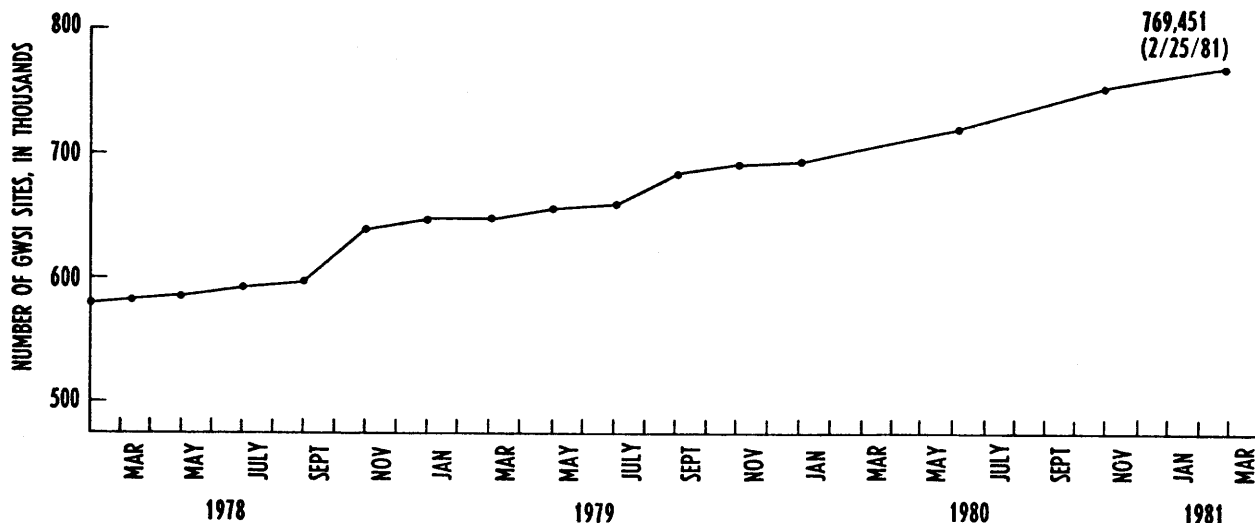

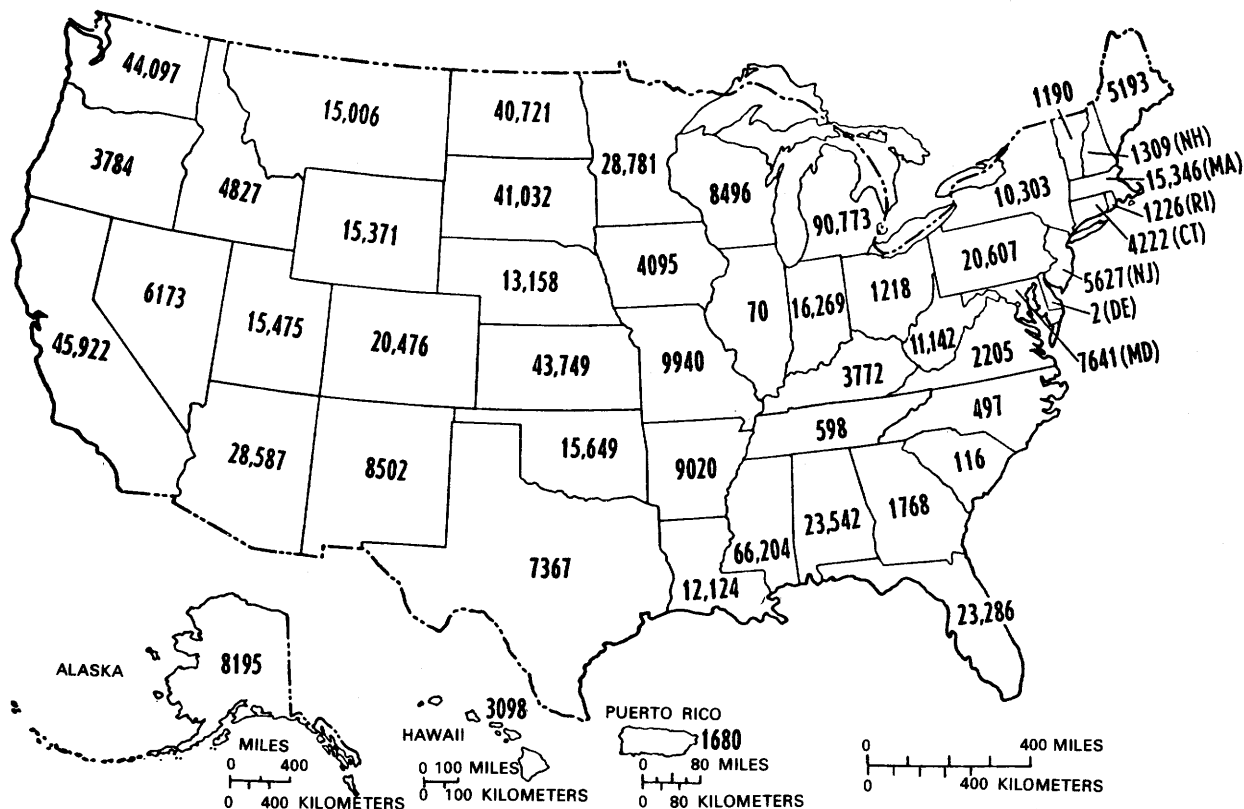FIGURE 2.—Increase in the number of sites in the GWSI data base.

FIGURE 3.—Number of GWSI sites per State and Puerto Rico.

RETRIEVAL OF DATA FROM GWSI

Once data reside in the GWSI, their retrieval is relatively simple. This capacity for quick, efficient retrieval is the primary purpose for choosing a DBMS for storage of ground-water data. The SYSTEM 2000 DBMS "Natural Language" (MRI Systems Corp., 1974b) computer program allows persons not trained in computer languages to use brief, English-like commands to retrieve simple printouts of data. A water-level table produced by using this program is shown in figure 4. For more elaborate presentation of data, a feature called "Report Writer" (MRI Systems Corp., 1974c) is available as part of the DBMS.

If the "Natural Language" and "Report Writer" facilities are insufficient for retrieving data in a prescribed format, SYSTEM 2000 has an additional feature, "Programing Language Extension" (PLEX) (MRI Systems Corp., 1979) that can include prescribed SYSTEM 2000 statements in the code of a higher level programing language, such as COBOL, FORTRAN, and PL/I. With PLEX, any GWSI data item can be manipulated at the user's discretion. The user may produce specialized reports, use statistical or graphical routines, and pass data to or merge with other computer files. The Survey has several PLEX computer programs that produce report tables, X–Y plots, and map plots for many of the data in the GWSI (see figures 5, 6, and 7).

USERS AND USE OF THE GWSI

The principal contributors to, and users of, the GWSI are personnel of the Survey. However, many engineering and environmental consultants retrieve data from the GWSI file, as do university researchers and State and local governmental agencies. Individuals also request ground-water information for their own use.

An evaluation of the ground-water resources of an area generally begins with a perusal of the existing data. For many areas, GWSI provides this starting point by supplying information about many of the

```
LIST/REPEAT SUPPRESS/ C1,C235,C237
----
 WH C1 EQ 392854106024501 OR
----
C1 EQ 393439106055901 OR
----
C1 EQ 393633105580601:
```

* SITE-ID	WL-MEAS-DATE	WL-MEASUREMENT
***		
* 392854106024501	08/10/1976	19.73
*	09/13/1973	21.00
*	09/17/1975	20.31
*	10/14/1974	25.44
* 393439106055901	08/09/1977	18.91
*	08/10/1976	12.40
*	09/14/1973	11.88
*	09/17/1975	11.96
*	08/09/1978	13.23
*	08/22/1979	11.89
* 393633105580601	08/10/1976	40.66
*	09/23/1977	42.27
*	09/13/1973	43.41
*	09/17/1975	41.89
*	10/14/1974	43.90
*	08/09/1978	41.62
*	08/22/1979	43.39
*	08/07/1980	43.58

FIGURE 4.—Water-level table produced by using a "Natural Language" retrieval command, which is listed above the table.

LOCAL NUMBER		ALTITUDE OF LAND SURFACE (FEET)	USE OF SITE	USE OF WATER	OWNER	PRINCIPAL AQUIFER	TEMPERATURE (DEGREES C)	SPECIFIC CONDUCTANCE (UMHOS/CM AT 25 C)
SC01604632DDAC1	0	75	W	H	HAZENBERG, HANK	110QRNR	--	--
SC01604634BCBC1	0	50	W	H	ERICKSON, ARNE	--	--	--
SC01604634BCDD1	0	55	W	H	COOK, TIM	110QRNR	--	--
SC01604634BCDD2	0	55	W	H	BLUSH, ROBERT	110QRNR	--	--
SC01604634CBAD1	0	35	W	H	HILL, FRANK	110QRNR	3.0	70
SC01704429CBDC1	0	90	U	U	USAF KGSLM, 3RD RADIO	110QRNR	--	--
SC01704510DCCC1	0	60	W	H	ANGASAN, RALPH	110QRNR	--	--
SC01704514BDDD1	0	80	W	C	RCA WH ALC, KING SLM	110QRNR	--	--
SC01704522BBBC1	0	50	W	H	WILLIAMS, BERTHA	110QRNR	--	--
SC01704522CCAB1	0	25	W	P	FAA, KING SLM	110QRNR	5.0	1100
SC01704523ABAC1	0	75	W	--	USAF, KING SLM	110QRNR	--	--
SC01704523ACCB1	0	50	U	U	USAF, KING SLM	110QRNR	--	--
SC01704523ADCC1	0	75	Z	U	USAF, KING SLM	110QRNR	--	--
SC01704523BACD1	0	75	W	P	USAF, KING SLM	110QRNR	5.0	280
SC01704523BACD2	0	75	W	P	USAF, KING SLMN	110QRNR	--	--
SC01704523BBAB1	0	75	W	P	USAF, KING SLM	110QRNR	--	--
SC01704523CDCB1	0	35	U	U	WOOD Z, LODGE	--	--	--
SC01704523CDCB2	0	35	W	C	WOOD Z, LODGE	--	--	--
SC01704523CDCB3	0	35	W	C	EDDIES, FRPLC IN	--	--	--
SC01704523CDCD1	0	35	W	Z	ADF & G, KING SLM	--	--	--

Explanation of codes:

(1) Use of Water
W Withdrawal of Water
U Unused
Z Destroyed

(2) Use of Water
H Domestic
U Unused
C Commercial
P Public Supply
Z Other

(3) Principal Aquifer
Quaternary System

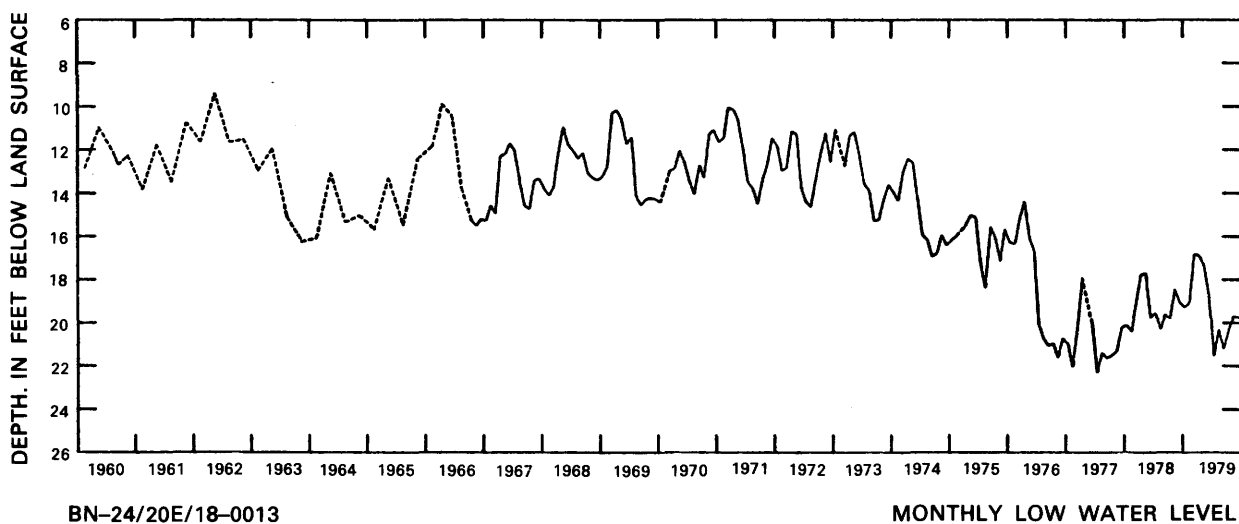FIGURE 5.—Report table of GWSI data produced by PLEX program.

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MONTHLY LOW WATER LEVEL

FIGURE 6.—Hydrograph showing water levels in a typical well during a 20-year period of record. Dashed line indicates period of intermittent record.
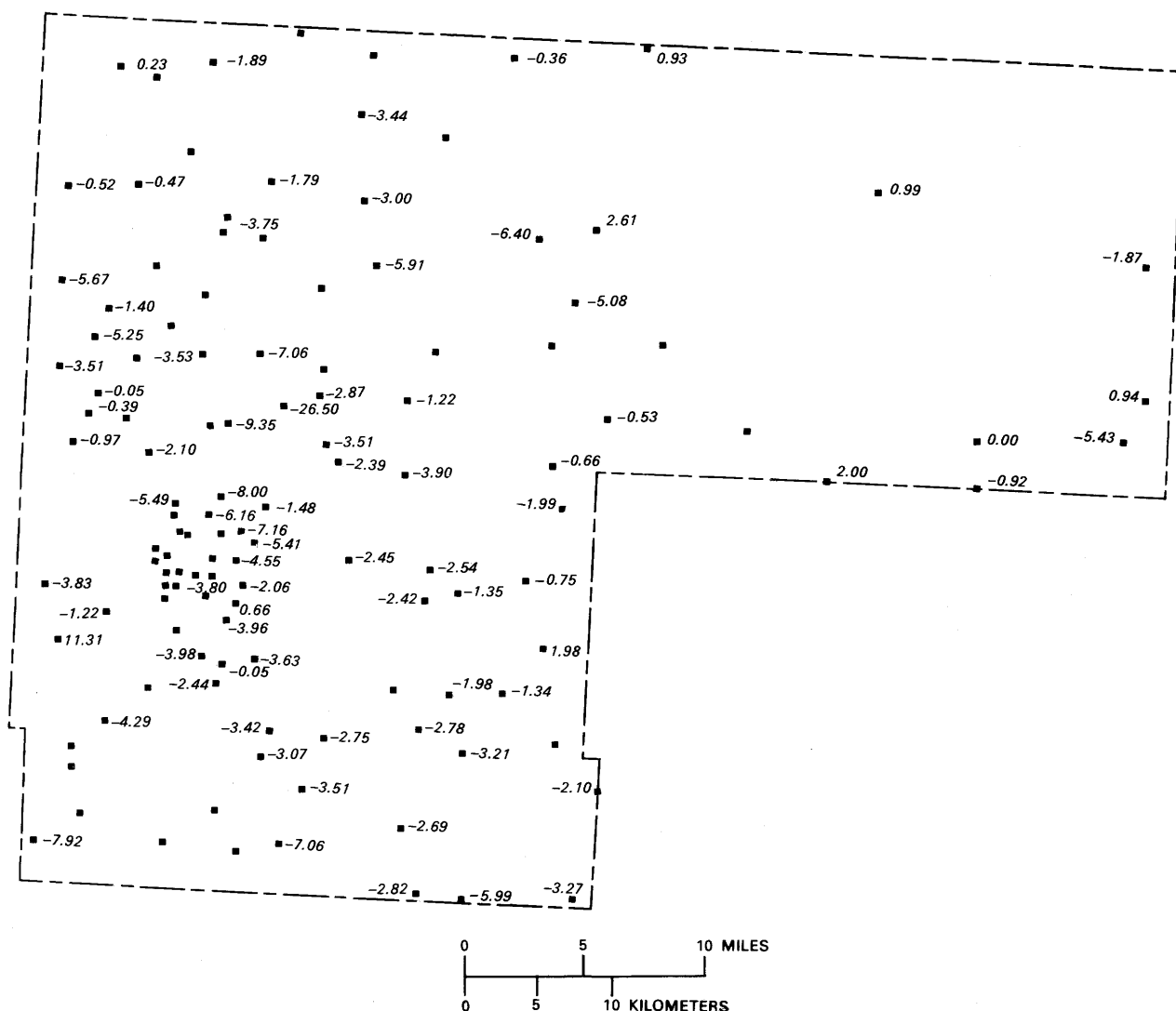
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FIGURE 7.—Example of computerized map plot from the GWSI data base, on a Kansas county outline. Water level changes, in feet, are indicated at many sites.

existing wells and springs. Historical water-level data, from which hydrographs and maps of potentiometric surfaces may be constructed, are particularly helpful. These data also may aid in interpreting the effects of climate fluctuations and resource development in the area under study.

Data may be obtained from the GWSI either by submitting a request to NAWDEX (Edwards, 1978) or by establishing direct, online access to the data bases. NAWDEX services are available through a nationwide network of Assistance Centers (Edwards, 1980) located in 45 States and Puerto Rico. The locations of these centers are given in table 2, and a free directory of all Assistance Centers may be obtained from NAWDEX (see the address given below). Charges for retrieving data are assessed at the rate of the actual cost of retrieval of the requested data from the GWSI. Those users desiring direct, online access to the GWSI must sign a Memorandum of Agreement with the Survey for this purpose and must assume full financial responsibility for their use of the Survey's computer system. This agreement authorizes users to input data to the GWSI, as well as make retrievals from it. Requests for direct access to the data base must be submitted in writing to the Program Manager, National Water Data Exchange, U.S. Geological Survey, 421 National Center, Reston, VA 22092.

TABLE 2.—*Locations of NAWDEX Assistance Centers*

ALABAMA	Tuscaloosa.
ALASKA	Anchorage.
ARIZONA	Tucson.
ARKANSAS	Little Rock.
CALIFORNIA	Menlo Park.
COLORADO	Lakewood (Denver) and Ft. Collins.
CONNECTICUT	Hartford.
FLORIDA	Tallahassee, Miami, Orlando, and Tampa.
GEORGIA	Doraville (Atlanta).
HAWAII	Honolulu (also serves American Samoa and Guam).
IDAHO	Boise.
ILLINOIS	Champaign.
INDIANA	Indianapolis.
IOWA	Iowa City (2 locations).
KANSAS	Lawrence.
KENTUCKY	Louisville.
LOUISIANA	Baton Rouge.
MARYLAND	Towson (also serves Delaware and District of Columbia).
MASSACHUSETTS	Boston (also serves Maine, New Hampshire, Rhode Island, and Vermont).
MICHIGAN	Okemos (Lansing) and Ann Arbor.
MINNESOTA	St. Paul.
MISSISSIPPI	Jackson.
MISSOURI	Rolla.
MONTANA	Helena.
NEBRASKA	Lincoln (2 locations).
NEVADA	Carson City.
NEW JERSEY	Trenton.
NEW MEXICO	Albuquerque.
NEW YORK	Albany and Syosset.
NORTH CAROLINA	Raleigh.
NORTH DAKOTA	Bismarck.
OHIO	Columbus.
OKLAHOMA	Oklahoma City.
OREGON	Portland and Salem.
PENNSYLVANIA	Harrisburg and Philadelphia.
PUERTO RICO	Ft. Buchanan (San Juan) (also serves Virgin Islands).
SOUTH CAROLINA	Columbia.
SOUTH DAKOTA	Huron.
TENNESSEE	Nashville.
TEXAS	Austin.
UTAH	Salt Lake City (2 locations) and Logan.
VIRGINIA	Richmond, Blacksburg, and Reston.
WASHINGTON	Tacoma.
WEST VIRGINIA	Charleston.
WISCONSIN	Madison.
WYOMING	Cheyenne.

CONCLUSIONS

Solution of today's complex hydrologic problems requires the timely availability of reliable ground-water data. The GWSI data base, in conjunction with the SYSTEM 2000 data base management system, provides these reliable and unbiased ground-water data for the hydrologist or planner who requires quick and easy access to them.

Standardization of input-retrieval procedures and data formats exists in the GWSI for all data, and the techniques of manipulating the ground-water data are the same throughout the United States. The goals of the Survey in establishing a nationwide ground-water data base, thus, have been accomplished.

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